Human Systems CoI Roadmap 2020

Organization of Presentation

- ## CoI Description and High Level Roadmap
  - Overview
  - Subarea Details
  - Overarching Message and Wrap-Up

- ## Detailed Roadmaps for Each Taxonomy Area

Background

Where we were last time/changes

- Organizational Restructuring
  - Army Futures Command
  - AF

Portfolio changes over last 5-10 years

- Divestitures
- Shift human-system design from human adaptation to technology adaptation approaches
- Developed series of individual focused research areas under Human-Autonomy Teaming (HAT):
  - 2016: Cybernetics
  - 2017: Human Variability Project
  - 2018(9): Human (Crew) Capability Enhancement
  - 2019: Novel Forms of Joint Human-AI Decision
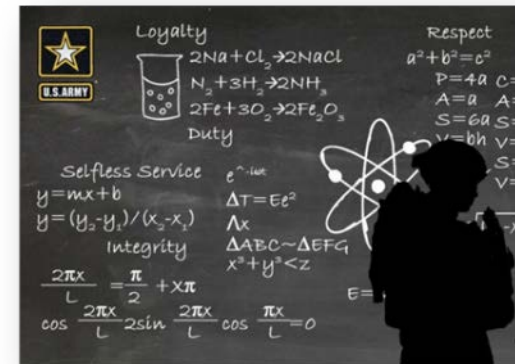
Vision and Mission

VISION
Develop and deliver technologies to enable, sustain, enhance, and quantify human performance for measurably improved mission effectiveness.

ENHANCE

ENABLE

SUSTAIN

MISSION
Enhance mission effectiveness through:

- Integrated simulations for mission training, experimentation
- Human-machine designs for mission effectiveness
- Assessment of operator effectiveness
- Protecting operators through battlespace stressors
- Mastering the political, military, economic, social, infrastructure, and information systems (PMESII) battle space

Human Systems CoI Taxonomy

Sub-Areas	Thrusts	
Personalized Assessment, Education, and Training	Personnel Selection and Assignment	
	Training Design, Assessment, and Readiness Monitoring	
	Advanced Learning Technologies	
System Interfaces and Cognitive Processes	Understanding Human/Cognitive Processing	
	Human-Machine Interaction and Aiding	
	System Level Interfaces and Teaming	
Protection, Sustainment, and Warfighter Performance	Sensing, Monitoring, and Assessment	
	Enhancement Technologies and Techniques	
	Bioeffects	

Human Systems Community of Interest Active Membership

STEERING GROUP

Dr. John Tangney (Navy)
Dr. Patrick Mason (Navy)

Dr. Kevin Geiss (AF)
Ms. Lisa Sanders (SOCOM)
Dr. Ben Petro (OUSD)

Dr. Corde Lane (Army)
Dr. Patrick Baker (Army)
Dr. Michelle Zbylut (Army)
Dr. Robb Wilcox (Army)

WORKING GROUP

Dr. Kelly Ervin (Army)
Ms. Rachel Weatherless (Army)
Dr. Jessie Chen (Army)

Ms. Roxanne Constable (AF)
Ms. Jody Wojciechowski (Army)
Ms. Karen Gregorczyk (Army)

Dr. Paul Chatelier (Navy)
Dr. Kristy Hentchel (Navy)

SUB-AREAS

Personalized Assessment, Education, and Training
Dr. Kendy Vierling (USMC)
Dr. Ben Files (Army)
Mr. Rodney Long (Army)
Dr. Pete Khooshabehadeh (Army)
Dr. Greg Ruark (Army)
Dr. Sae Schatz (ADL)
Dr. Harold Hawkins (Navy)
LCDR Pete Walker (Navy)
Dr. Mark Livingston (Navy)
Dr. Jim Pharmer (Navy)
Dr. Ray Perez (Navy)
Dr. Melissa Walwanis (Navy)
CDR Jeff Alton (Navy, OUSD)
Dr. Shannon Salyer (OPA)
Dr. Michael Nugent (DLNSEO)
Dr. Eric Sikorski (CTTSO)
Dr. Kimberly Pollard (Army)
Dr. Glenn Gunzelmann (AF)

Protection, Sustainment, and Warfighter Performance
Dr. Peter Squire (Navy)
Dr. Mike LaFiandra (Army)
Dr. John Ramsay (Army)
Ms. Betty Davis (Army)
Mr. John Player (Army)
LCDR Josh Swift (Navy)
Dr. Karl Van Orden (Navy)
Dr. Sandra Chapman (Navy)
Dr. Kristy Hentchel (Navy)
Mr. Keith King (Navy)
Dr. Curt Grigsby (AF)
Dr. John Schlager (AF)
Dr. Morgan Schmidt (AF)
Dr. Kendy Vierling (USMC)

Systems Interfaces and Cognitive Processes
Dr. Mark Draper (AF)
Dr. Laurie Fenstermacher (AF)
Dr. Jeff Palumbo (AF)
Dr. Tammy Chelette (AF/ Autonomy CoI)
Mr. Ed Davis (AF)
Mr. Eric Hansen (AF)
Dr. Tom McKenna (Navy)
Dr. Jeff Morrison (Navy)
Dr. Ami Bolton (Navy)
Dr. Rebecca Goolsby (Navy)
Dr. Katherine Cox (Army)
Dr. Caroline Mahoney (Army)
Dr. Jeff Hansberger (Army)
Dr. Jonathan Bakdash (Army)
Dr. Edward Palazzolo (Army)
Dr. Lisa Troyer (Army)
Dr. Adam Russell (DARPA)
Dr. Dale Russell (Navy)

HS CoI
CY19 Completed Events/Planned Activities

- **Annual Reliance 21 Meeting** — **Jan 2019**
- **CCDC-Soldier Center Familiarization Visit** — **Feb 2019**
- **NDIA S&ET Conference with CoI Poster** — **Mar 2019**
- **NDIA Human Systems Conference** — **Apr 2019**
- **Human Factors Engineering (HFE) TAG** — **Apr 2019**

  Held Together

- **CCDC- Army Research Lab Familiarization Visit** — **Apr 2019**
- **Data and Analytics Infrastructure Modernization Workshop** — **Jun 2019**
- **HS CoI/ASBREM Internal Research and Development Event** — **Jun 2019**
- **DE CoI Kickoff** — **Aug 2019**
- **HS CoI Steering Group/"All-Hands"** — **Sep 2019**
- **Roadmap Review** — **Nov 2019**
- **Interservice/Industry Training Simulation and Education Conference** — **Dec 2019**

S&T Investments Matrixed to Priority Modernization

2018 National Defense Strategy Technology Areas & OUSD(R&E) Top 11 vs. HS CoI Subareas

HS CoI Subareas	AI/ML	Autonomous Systems	Biotech	Cyber-security	Hyper-sonics	EW	Directed Energy	Missile Defense	Networked C3	Micro-electronics	"Big Data" Analytics
	Enabling /Enabled by	Enabling /Enabled by	Enabling/ Enabled by	Enabled by	Enabling	Enabling	Enabling	Enabling	Enabled by	Enabling /Enabled by	Enabled by
Personalized Assessment, Education, and Training	X	X		X		O	O	O	X		X
Protection, Sustainment, and Warfighter Performance	X	X	X				X	X	O	X	O
System Interfaces and Cognitive Processes	X	X		X	O				O		X
Areas most requiring HS R&D to achieve objectives	Now	Now	In near future	In near future	Now	Now	Now	Now	In near future	Now	Now

X Existing

O Potential

Service Demand Signals

DoD **2018 National Defense Strategy** **Close Combat Lethality Task Force**	Military readiness = more lethal force
	Performance optimization; sustained mission readiness in extreme environments
	Optimize the physical preparedness of personnel
	Prepare squad through realistic training in immersive high-stress environment
Army **The Army Vision** **The Army Strategy** **U.S Army Modernization Strategy**	Smart, thoughtful, innovative leaders → new talent mgt-based personnel system
	Soldier lethality spanning shooting, moving, communicating, protecting, sustaining
	Next Generation Combat Vehicle: Human and non-human teams at new levels
	Rapid expansion of synthetic training environments, simulations capabilities
Navy **A Design for Maintaining Maritime Superiority** **Naval R&D: A Framework for Accelerating to the Navy and Marine Corps After Next**	Augmented Warfighter Priority: Enhance decision-making and Human-Machine teaming
	Science-based practices to support leader development, better decision making
	Scalable Lethality: Enable directed energy (low cost, high precision standoff strike)
Air Force **Air Force Future Operating Concept** **The Science and Technology 2030 Initiative**	Human-Machine Interface: Right information + right person + right time = right decision
	Agile innovative airmen in performance optimized teams for multi domain operations
	Rapid effective decision making

Success Stories

Battlefield Assisted Trauma Distributed Observation Kit

AF/Army/SOCOM

Advanced Small Unit Decision Making

Marine Corps

Techniques for Soldier-Exoskeleton Analysis

Army

Secure LVC Advance Training Environment

AF/Navy

Measuring & Advancing Soldier Tactical Readiness

Army/CCLTF/USAF

Allied Intelligent Multi-UxV Planner with Adaptive Collaborative Control Technologies
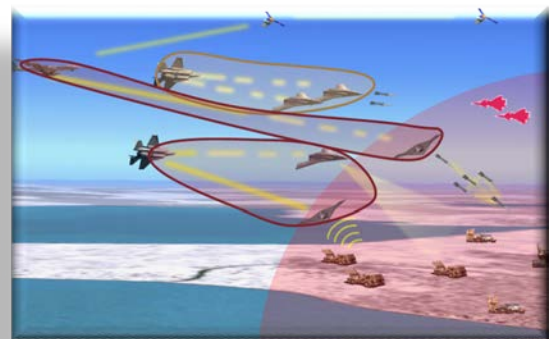
Army/Navy/AF/TTCP

Joint Terminal Area Controller Virtual Trainer

Marine Corps

Upcoming Products

Adaptive Teamwork with Layered Airman-Machine Interfaces and Systems

Air Force

Voluntary Transfer Incentive Program

Army-ARL
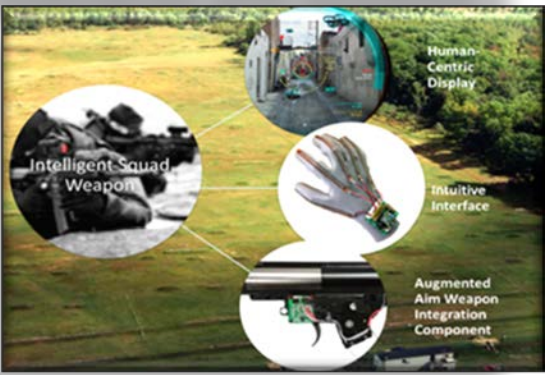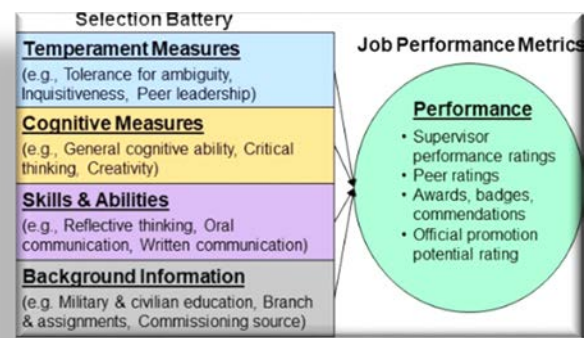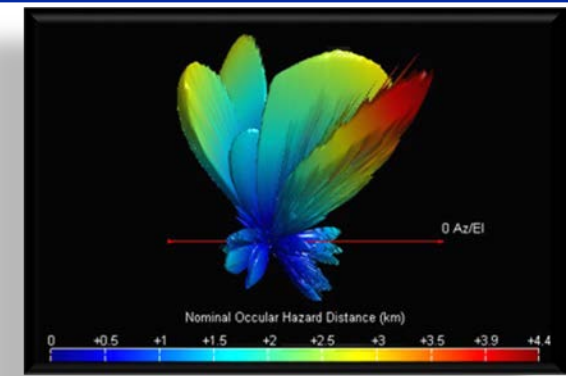
Probabilistic Risk Assessment/ Weaponeering Guides

Air Force

Human Agent Interactions for Intelligent Squad Weapons

Army

Cycle of Learning

Army-ARL

Musculoskeletal/Heat Injury Prevention

Navy

Divestitures

Air Force

- **Rely on industry for** cockpit displays, aircraft symbology, ejection seats, human detection and characterization

- **Rely on Defense Health Program for** altitude effects, high-G effects

- **Rely on Army for** night vision goggles

Army

- **Shifted priorities away from** sensation and perception and cognition

Navy

- **Rely on DTRA as the Executive Agent for** chem-bio defense

- **Rely on other agency investments for** neurobiology of learning

Mutual Col-to-Col Research Interests

ASBREM

- Autonomous medical evacuation
- Biomedical modeling and simulation
- Predictors of mental health and medical attrition
- Modernization of biotechnology data and analytics infrastructure

Autonomy

- Human-Machine Teaming (HMT)
- Verification and Validation (V&V)
- Trust

C4I

- Human Decision Making

DE

- Bioeffects

CWMD

- Dark web concerns
- Social network analysis
- Counter-terrorism research

Cyber

- Cyber selection and training
- Cyber situational awareness

ASBREM, Sensors, CWMD
Wearable physiological monitors

Cross-CoI Engagements

- **Hosted cross-CoI workshop:** *Modernizing DoD Biotechnology Data and Analytics Infrastructure*
- **Co-hosted HS/ASBREM Independent Research and Development (IR&D) Technology Interchange Meeting (TIM)**
- **ASBREM CoI State of the Science for Autonomous Medical Evacuation Workshop: Air Platforms, Autonomy, C4I, Energy and Power, and Sensors CoI Participation**
- **ASBREM's Walter Reed Army Institute of Research (WRAIR) evaluation of ARI TAPAS measures as predictors of mental health and medical attrition**
- **Joint Autonomy/HS ARAP for FY19**
- **Autonomy CoI's Autonomy Software Architecture Workshop**
- **Executing Joint-Service Autonomy Research Pilot Initiatives**

Significant engagements

Biotechnology

- **Data and Analytics Infrastructure Modernization Workshop**
  - Co-hosted by Dr. Alexander Titus – Assistant Director for Biotechnology, HS CoI, and Human Systems Directorate OUSD(R&E)
  - Intent was to inform the POM and understand needs/limitations/potential for modernizing the data infrastructure associated with biotechnology within the DoD
  - Participants: DTRA, DIU, AI AD, DARPA, Army, Navy, Air Force, USMC, Autonomy CoI, ASBREM CoI, DoD High Performance Computing, Veterans Affairs

Other

- **Close Combat Lethality Task Force Human Performance Community of Practice**
- **Strengthening Teamwork for Robust Operations in Novel Groups (STRONG) Innovation Summit**
- **Lethality Cross-Functional Teams technical briefings/demonstrations**

International Collaborations

NATO

- *Upcoming*: **Information Systems Technology Research Task Group (RTG)**
- **Human Factors & Medicine (HFM) RTGs**
  - Augmentation Technologies RTG (HFM-297) special event at I/ITSEC

Bilateral Research

- **AFRL & UK Laser Exposure Ocular Effects Project Agreement Success**
- **AFRL & Japan Collaboration Investigating Jet Propulsion (JP) JP-4/8 Fuel Exposures**

Technical Cooperative Program (TTCP)

- **Allied IMPACT (AIM) & TTCP Autonomy Strategic Challenge**
- **Human Resources and Performance Group (HUM) JP-1 Wearable Assistive Technologies**
- **C4I Group Technical Panel 41 All-Source Analytics**
- **TTCP HUM TP-23 (Human Resources)**
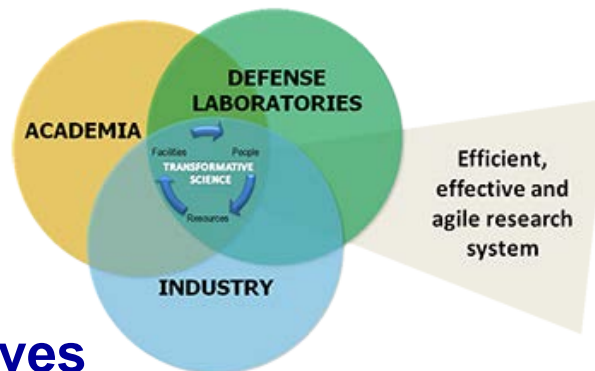
U.S./UK Stocktake

- **Principals meeting June 25-27, 2019 Aberdeen Proving Ground, Maryland.**
- **Data Science for HR Forecasting (February 2019)**

Academic Collaborations

Centers of Excellence

- **Human-Machine Teaming at Carnegie Mellon**
- **Biotechnology at Northwestern**
- **Directed Energy Bioeffects Institute (DEBI)**
- **TUFTS– Center for Applied Brain and Cognitive Sciences**

Multidisciplinary University Research Initiatives

- **Active Perception and Knowledge Exploitation in Navigation and Spatial Awareness**
- **Neural Circuits Underlying Symbolic Processing in Primate Cortex and Basal Ganglia**
- **A Computational Cognitive Neuroscience Approach to Understanding Event Representation and Episodic Memory**
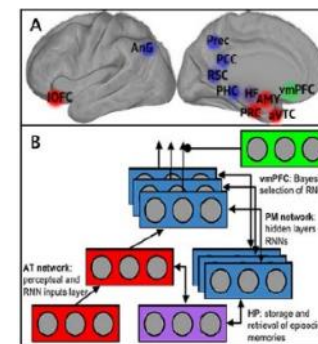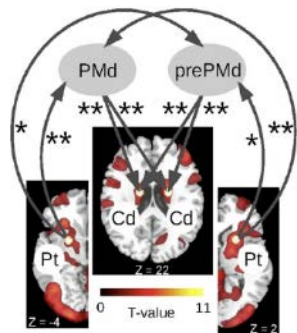
ARL Open Campus

ARL's Open Campus is a collaborative endeavor, with the goal of building a science and technology ecosystem that will encourage groundbreaking advances in basic and applied research areas of relevance to the Army. Through the Open Campus framework, ARL scientists and engineers (S&Es) will work collaboratively and side-by-side with visiting scientists in ARL's facilities, and as visiting researchers at collaborators' institutions.

Organization of Presentation

- **CoI Description and High Level Roadmap**
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- **Detailed Roadmaps for Each Taxonomy Area**

1.0 Personalized Assessment, Education, and Training

Right Person, Right Job, Right Skills

VISION

A readiness ecosystem that ensures the right person has the knowledge, skills, and experiences to be mission ready for the 21st century operating environment

Metrics: Selection, Assignment, & Training Assessment

Models: Readiness and Performance Monitoring

Practices: Learning Sciences adapted to Military Needs

Technologies: Virtual, Augmented, & Mixed Reality and Intelligent Tutors across the Training Spectrum

OPERATIONAL OPPORTUNITIES:

- Train-as-we-fight opportunities with Live Virtual Constructive (LVC) environments for current and future systems
- Learning environments tailored to training objectives
- Advanced learning technologies that facilitate personalization and deliberate practice at point-of-need
- Technological advances that enable new training paradigms
- Individualized, proficiency-based assessments of training effectiveness and operational performance
- Talent management functions personalized through big data

ENDURING CHALLENGES:

- Increased technological parity with adversaries
- Inadequate ranges for training advance weapon system capabilities (e.g., 5th-gen aircraft, residential encroachment)
- Live training potentially reveals capabilities to adversaries.
- Dynamic, evolving operational environments and adversaries
- Requirements outpace opportunities and resources to train
- Ineffectiveness of one-size-fits-all, Industrial Age training
- Sparse data for manpower and training decisions
- Limited capacity to leverage personnel diversity

1.1 Personnel Selection and Assignment

1.1.1: Individualized Measures of Aptitude

1.1.2: Career-Long Outcome Measures **GAP**

1.1.3: Predictive Models for Performance and Retention

1.2 Training Design, Assessment, and Readiness Monitoring

1.2.1: Data and Learning Sciences

1.2.2: Cognitive and Performance Modeling

1.2.3: Innovative Training Design and Methodologies

1.3 Advanced Learning Technologies

1.3.1: VR/AR/MR and Integrated Simulations

1.3.2: Intelligent Tutoring Systems

TECH/CAPABILITY GAPS:

- Developing and integrating predictor measures that have individualized precision
- Developing or improving measures of operational performance and behavior that could inform decisions about career trajectory and future assignments
- Integrating currently stove-piped predictive models that are based on more than just group probabilities
- Warehousing and using (big) proficiency-based performance measures to inform training and operational decisions
- Adapting learning sciences to military contexts
- Conducting training and assessment in human-machine teams
- Developing and employing models, agents, and algorithms as synthetic training entities and for real-time readiness monitoring
- Securely integrating LVC environments
- Assessing virtual, augmented, and mixed reality technologies for training
- Creating software instructors for personalized training interventions
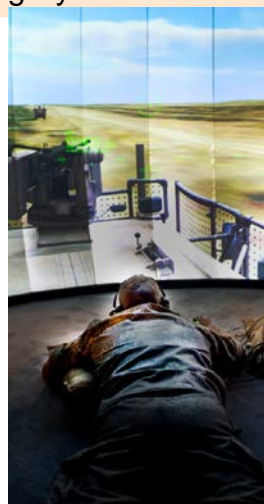
Accelerating the Development of Small-Unit Decision Making

Challenge: Develop a suite of integrated technologies that enable Marine small-unit leaders to easily and rapidly tailor simulation-based training with real-world terrain for enhanced decision-making training and after-action review (AAR).

Accomplishments:

- Spartan After Action Review (SPAAR) Tool

- Adaptive Perceptual Cognitive Training System (APACTS)

- Synthetic Environment Terrain (SET) Tool

- The Rapid Aerial PhoTogrammetric Reconstruction System (RAPTRS)

- Transition: USMC deployed a Tactical Decision Kit (TDK) with ADUSDM prototype software early to all 24 USMC Infantry battalions in 2017. USMC feedback informed two subsequent TDK software releases prior to FY19 final transition.

Applied Research Supports Inaugural RED FLAG – RESCUE

Challenge: Improve training effectiveness to the domain of personnel recovery, develop proficiency based training metrics, and integrate LVC capabilities.

Accomplishments:

- Range-less OTI for situational awareness and facilitated after-action reviews

- Integrated GovCloud and IoT sensors

- Big Data Approach to team of team metric development

- High Fidelity Medical Simulators

- Adapt common tools to evaluate training effectiveness.

- Single test battery to support the Voluntary Transfer Incentive Program (VTIP) / selection for special assignments
- Battery components differentially predict performance for each functional area/assignment
- Validation required for each functional area/assignment

Officer Special Assignment Selection Battery

Temperament Measures
(e.g., Tolerance for ambiguity, Inquisitiveness, Peer leadership)

Cognitive Measures
(e.g., General cognitive ability, Critical thinking, Creativity)

Skills & Abilities
(e.g., Reflective thinking, Oral communication, Written communication)

Background Information
(e.g. Military & civilian education, Branch & assignments, Commissioning source)

Job Performance Metrics

Performance
- Supervisor performance ratings
- Peer ratings
- Awards, badges, commendations
- Official promotion potential rating

Strategist (FA59)
"Perform four unique functions: strategic appraisal; strategic and operational planning; joint, interagency, intergovernmental, and multinational (JIIM) integration; and strategic education."
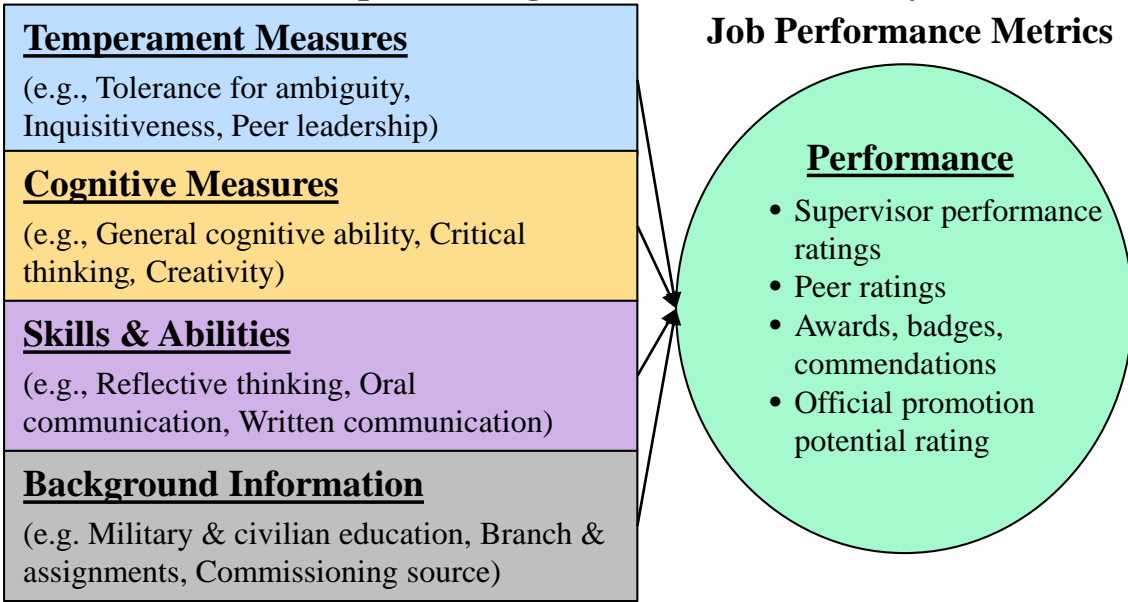Status: Transitioned

Foreign Area Officer (FA48)
"Advise senior leaders, provide cultural expertise, build/maintain relationships with foreign leaders, coordinate/implement security cooperation programs, and report on foreign nation activities."
Status: In Development

Modeling & Simulation (FA57)
"Understand the capabilities of simulation and Battle Command Systems; provide the training and operational environment to conduct operations and mission planning and mission rehearsal exercises."
Status: Planned

Force Management (FA50)
"Understand the art and science of *how the Army runs;* translate strategy into structure; design organizations, build structure, allocate manpower/equipment, execute organizational authorizations, and build investment strategies."
Status: Initial Development

Senior Advisors
"Perform ministerial-level advising to support development of the capacity and capability of foreign security forces and their supporting institutions."
Status: In Development

Civil Affairs
"Use critical skills associated with politico-military awareness, foreign language, and cultural expertise to develop, plan, coordinate, command, control, and evaluate strategic and tactical operations, policies, doctrine and activities for civil affairs programs."
Status: Initial Development

Systems Interfaces & Cognitive Processes

Effective, Natural Human-Machine Teaming

VISION

Warfighters teamed with agents and machines through intuitive, individualized, and adaptive interactions that enhance mission effectiveness.

Multi-Domain Operations   *Manned-Unmanned Teaming*   *Team Performance Assessment*   *Quantified Warrior*

OPERATIONAL OPPORTUNITIES:

• Enhance warfighter effectiveness by coupling humans & intelligent machines to maximize performance in the fog of war

• Real-time measurement, assessment and prediction of warfighter performance & functional state

• Adaptive human-machine interfaces for optimized weapon system and warfighter performance in contested environments

• Rapid, intuitive decision aiding & course of action analyses

• Manage perceptual abilities to exploit information throughput

• Field demonstrations in applied environments

ENDURING CHALLENGES/NEEDS:

• Mission effectiveness metrics & baselining

• Workflow models for teams

• Robust cognitive models & architectures for autonomous agents

• Multisensory adaptive interfaces that enhance, not interfere

• Robust, reliable natural language interfaces

• Dynamic calibration of system transparency to need

• Contextually aware dynamic decision support

• Tools for individual & team functional state assessment (Sensors & Algorithms)

• Identification of biomarkers for operator performance

• Coordination methods for teams of multi-adaptive systems.

• Interfaces that adapt to individual differences

2.1 Understanding Human/Cognitive Processing [WITHIN HUMAN]

2.1.1: Perception (Unitary and Multi-sensory)

2.1.2: Dynamic Operator Functional State Assessment

2.1.3: Cog Neuroscience/Performance Augmentation

2.2 Human-Machine Interaction and Aiding [HUMAN-MACHINE]

2.2.1: Advanced Interface Methods (Adaptive, Multi-modal)

2.2.2: Intelligent Decision Aiding/Support

2.2.3: Dynamic/Adaptive Task Allocation and Authority Transfer

2.2.4: Trust Calibration & Transparency

2.3 System Level Interfaces & Teaming [HUMAN-SYSTEM]

2.3.1: System Analyses and HSI (Organization)

2.3.2: Team Processes, Performance, & Metrics (Shared SA;Cohesion)

2.3.3: Data Analytics/ Socio-Cultural Analytics/ Exploitation Tools

2.3.4: System Interface Design and Application

TECH/CAPABILITY GAPS:

- **Perception research– especially in areas of multi-sensory modeling/exploitation**
- **Design guidelines for reliable, real-time assessment of operator functional state**
- **Joint cognitive H-A decision making**
- **Baselining for envisioned capabilities**
- **Foundational research on distributed H-H-A teaming affordances**
- **Team performance metrics development**
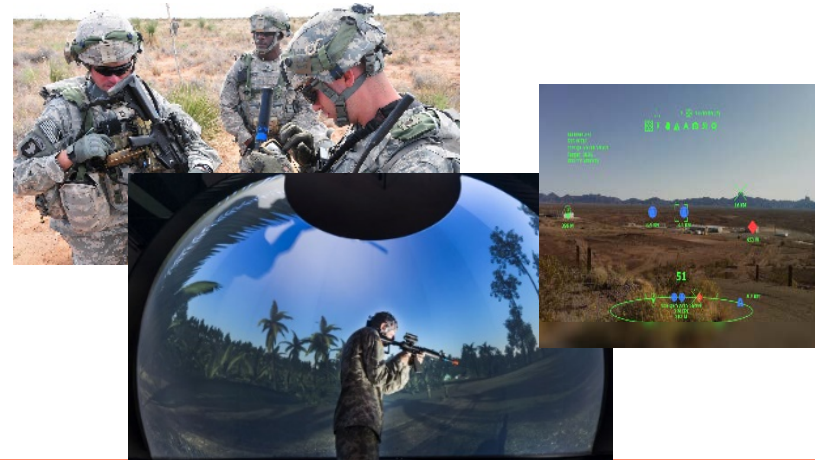
Bot Identification and Threat Evaluation Dashboard Demonstration

Challenge: Due to their ability to spread hostile discourse and utilization of networks that scale to provide maximum reach, it is essential to educate analysts on bot-farm threats. However, it is currently outside of doctrinal training opportunities.

Technical Approach: Developed a dashboard that leverages advanced analytics and methods for identifying/investigating bot behavior, evaluates the investigation/evaluation of bot signatures and impact to inform effective countermeasure strategies. The dashboard includes bot trackers, models, and visualizations to detect, understand, and counter such activities.

Impact:
- Prototype demonstrated in Baltops 2019 annual exercise with successful identification of bot farms and strategies.
- Numerous coalition analysts were trained in this new type of information warfare using the BITE tool.

Speech-to-Text for Enhanced PED (STEP) Operational Assessment
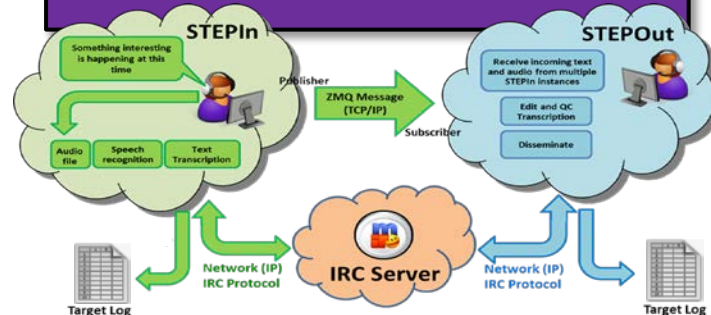
Challenge: Improve the ISR Processing, Exploitation and Dissemination (PED) process

Technical Approach: Automate the capture, transcription, and dissemination of Full Motion Video callouts by introducing automatic speech recognition technology.

Customize COTS software for operational chat and adapt it to the vocabulary and sentence structure used by video analysts.

Impact:
- Highly accurate (> 97%) automated transcription capability
- Significantly reduces screener workload and improve PED operations efficiency with reduced crew construct
- Up to 51% decrease in callout dissemination times
- USSOCOM, NGA and ACC recommending full-scale deployment of STEP

Allied IMPACT (AIM)

Challenge: Enhance, demonstrate and evaluate the military utility of best-of-breed human-autonomy command & control (C2) methods to enable future FVEYS joint operations involving autonomous systems.

Technical Approach

1) Begin with core US-developed capability: IMPACT human-autonomy C2 research testbed for single operator management of multiple unmanned systems.

2) Integrate "best-of Breed" FVEY related technologies.

3) Develop three military–vetted operational use cases

4) Train 7 military SMES from 4 nations for weeklong evaluation.

5) Evaluate systems & interface concepts via simulation & live-trial exercises at Autonomous Warrior 2018 (Jervis Bay, AU)

S&T Accomplishments

- Single operator management of 17 unmanned assets (5 live assets: air, sea & ground platforms)
  - Average % Mission Complete = 92.12%
  - Faster response times to unexpected events
  - Acceptable operator workload & situation awareness
- Improved interoperability of emerging FVEYS autonomous systems
  - 22 components integrated from 14 organizations, 5 nations
- 10 novel human-autonomy interface tools evaluated by 7 SMES
  - Big wins: play calling, intelligent aiding, HMI design
- Novel data-logging capability for rapid, interactive after-action reviews

SME-Identified Applications

- Base defense/counter-UAS C2/multi-domain C2
- ISR/route surveys/battle damage assessment management
- Overwatch/escort
- Peace support ops/HADR

Protection, Sustainment, and Warfighter Performance
Ensuring Warfighter Safety and Survivability

VISION

Enable superiority of Warfighters by understanding and overcoming operational stressors, and providing protection from threats in their environment.

Nutrition and Sustainment

Exoskeletons for Physical Augmentation

Wearable sensor technology

Protection and performance optimization

OPERATIONAL OPPORTUNITIES:

- Ubiquitous and unobtrusive real-world, real-time performance assessment will provide information on warfighter readiness
- Optimizing Warfighter performance by understanding the impact of individual differences
- Enhanced technologies for optimization of warfighter load resulting in reduction in metabolic cost and increase in operational performance
- Enable effective use of directed energy systems through understanding of bioeffects
- Optimized nutrition to modulate and enhance health and performance

ENDURING CHALLENGES:

- Real-world, real-time performance assessment relies on large amounts of data and advanced algorithms that have not yet been developed.
- Differences in the ways individuals respond to stress require individualized models that account for human variability in order to optimize performance.
- Warfighters are exposed to combinatorial stressors that complicate study outcomes related to stress-induced health and performance decrements
- Transitioning from correlative biological measures to causative performance outcomes

3.1 Sensing, Monitoring, and Assessment

3.1.1: Sensing and Monitoring

3.1.2: Assessment

3.2 Enhancement Technologies and Techniques

3.2.1: Training Enhancements

3.2.2: Physical Augmentation

3.2.3: Molecular Interventions & Treatments

3.3 Bioeffects

3.3.1: Laser

3.3.2: Radio Frequency

3.3.3: Novel Weapons Effects
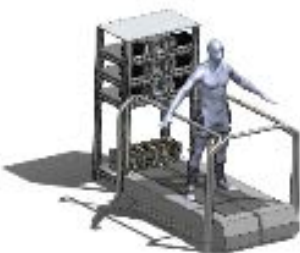
<u>TECH/CAPABILITY GAPS:</u>

- Sensor technology and the data collection/analysis infrastructure that is needed in order to collection real-time real world performance data, and make that data useful, are lacking.
- Algorithms that account for the influence of human variability on warfighter performance need to be developed.
- Understanding the who, what, when, and how concerning the application of materiel and non-material enhancement interventions (e.g. neurostimulation)
- Understanding of how the gut microbiome responds to exposures (military stressors, nutrient intake), impacts of these responses on nutrition status and performance, and whether nutrition interventions could modulate this axis to optimize warfighter performance is lacking
- Synthetically-engineered microbiome for targeted physiological monitoring, real-time stress attenuation and biological function need to be developed.
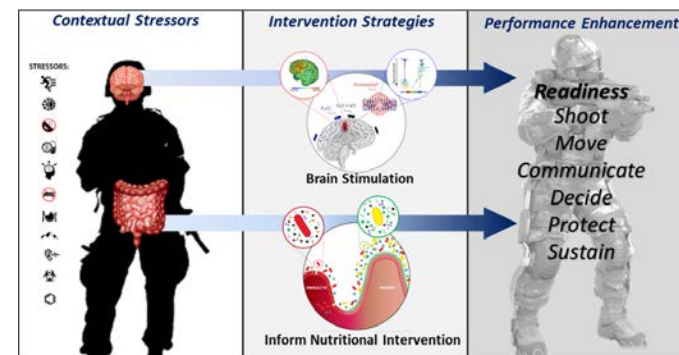
Dynamic Marksmanship Characterization: Novice vs Expert

9 Novice Marksmen
MOS:11B
Home Unit (<1 yr): 101st, 82nd, or 10th
Completed both Basic Rifle
Marksmanship and Advanced Rifle
Marksmanship training
Qualification 1 Sharp Shooter, 8 Expert
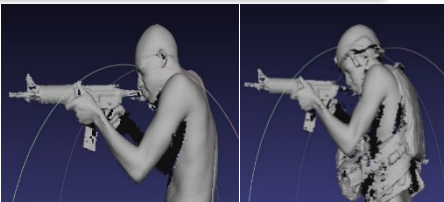
9 Expert Marksmen
Home Unit: AMU or MMTC
Competitive Shooters or Instructors
Met definition of expert
Qualification 9 Expert
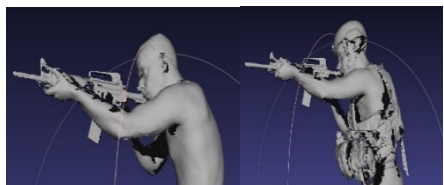
Challenge: Marksmanship is a fundamental skill for all Soldiers. Scientific understanding of the biomechanical factors that comprise a novice vs. an expert shooter in dynamic, operationally relevant settings is limited. Current qualification criteria for marksmanship does not address physical performance attributes.

S&T Accomplishments:

- Transitioned results to MCOE DOTD Marksmanship Annex through a Knowledge Transition Agreement.
- Development of a Tactical Stress Marksmanship Assessment to be incorporated in short range marksmanship assessments course
- Generated findings and translated the information into current Army marksmanship doctrine and current training methods by MMTC instructors

Closed-Loop Oxygen Generation and Delivery Program

Challenge: Maximize safe oxygen delivery and minimized oxygen/power consumption.

S&T accomplishments:

- Successful mitigation of hypo/hyperoxemic events in pre-clinical/clinical models,
- Generated a novel mechanical ventilation/oxygen concentrator interoperable system, and
- Received FDA Investigational Device Exemption to conduct a first-of-its-kind clinical trial utilizing closed loop control of oxygen delivery during mechanical ventilation in trauma patients

Measuring & Advancing Soldier Tactical Readiness & Effectiveness (Pilot)

Pre-Mission → Mission → Post-Mission

Challenge: Identify the human performance x-factors that reliably predict sustained Soldier and Squad collective lethality

Technical Approach: The MASTR-E pilot study launched a paradigm shift in how we operationalize science as an Army. Over 100 scientists, engineers, and technologists across nine (9) organizations participated in the study which included three live-fire 72-hour field exercises with pre, during, and post exercise data collections across 4 domains: health, physical, cognitive and social-emotional.

S&T Accomplishments:

- 46 complete data sets were collected across three platoons
- Major lessons learned were identified and documented to enhance future field studies
- MASTR-E pilot in-house database has been established using SQL and Python
- Live-fire marksmanship scoring tool was developed and implemented

S&T accomplishments Continued:

- Simulated marksmanship performance assessment was developed utilizing both static and dynamic components and varying heights and target distances
- CCDC CBC – added capability of quantifying large quantities of salivary samples for eight stress and fatigue related biomarkers using a validated novel mass spectrometry methodology

Example Research Outcomes:

Lethality:
- Soldiers with greater Weapons Qualification Scores (WQS) had >15% reduction in target acquisition time and >60% reduction in aiming time during dynamic shooting tasks; no effect of WQS on static shooting performance was found

Health:
- Soldiers have higher cortisol levels than average civilian cohorts
- Soldiers exhibited clinically-relevant levels of excessive daytime sleepiness pre- and during the mission and were at risk for chronic sleep restriction and poor sleep quality even prior to deployment

Cognitive:
- The stressful anticipation of a mission may shift Soldiers from long-term delayed decisions to impulsive ones

Physical:
- Following a 6 mile (9.7 km), loaded ruck (50% BW) march tactical foot march with ruck sacks and mission equipment (50% BW), Soldiers entered the mission with 8-10% muscle weakness in their abs, hip flexors and quads

Social-Emotional:
- Soldiers who feel that their leaders maintain open lines of communication and involve them in decisions achieve and maintain greater team cohesion

Organization of Presentation

- **CoI Description and High Level Roadmap**
  - Overview
  - Subarea Details

  - Overarching Message and Wrap-Up

- **Detailed Roadmaps for Each Taxonomy Area**

Key DoD Service Labs, Centers

- **Air Force: Air Force Research Laboratory (AFRL)**

- **Air Force: JBSA - Ft Sam Houston – DE Bioeffects**

- **Army: Combat Capabilities and Development Command (CCDC) Army Research Lab (ARL), Aberdeen Proving Ground (APG)**

- **Army: Army Research Institute for the Behavioral and Social Sciences (ARI)**

- **Army: Combat Capabilities and Development Command (CCDC) Soldier Center**

- **Army: Army Data and Analysis Center**

- **Navy: Naval Research Lab**

- **Navy: Naval Surface Warfare Center**

- **Navy: NAVAIR**

- **Navy: SPAWAR**

- **Advanced Distributed Learning (ADL)**

Engagement ops with industry

- Internal Research & Development Technical Interchange Meeting

- National Defense Industrial Association Human Systems Division

- USAF S&T 2030 Vanguard Pipeline (Wright Dialogue with Industry)

- Advanced Distributed Learning iFEST

- National Defense Industrial Association S&ET Conference

- Interservice/Industry Simulation Training & Education Conference

- TechStars

- Modern Day Marine Expo (MDM), Quantico, VA

- Naval Future Force S&T Expo, Washington, DC

Future directions

- **Amplifying our cross-COI collaborations**

  - embedded, shaping the direction – at COI level vs SME level;

- **Lab familiarization continuation**

- **Expansion to operational exercises**

- **Lead/leverage/watch discussion – not just amongst the services – CoI perspective on who we should be partnering with in industry and academia**

Organization of Presentation

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Army	Navy	USMC	AF	Other

1.1 Personnel Selection and Assignment

	FYDP						
	2019	2020	2021	2022	2023	2024	2025
1.1.1 Individualized Measures of Aptitude							
Holistic Personnel Assessments	███ (Army)						
Leadership Competencies for Complexity and Uncertainty	███ (Army)						
Team-Based Personnel Assignment and Performance	███ (Army)						
1.1.2 Career-Long Outcome Measures							
GAP							
1.1.3 Predictive Models for Performance and Retention							
Data Science for Talent Management	███ (Army)						
Navy Life	▌(Navy)						

1.2 Training Design, Assessment, and Readiness Monitoring

	FYDP						
	2019	2020	2021	2022	2023	2024	2025
1.2.1 Data and Learning Sciences							
Competency-Based Learning Management	███ (Other)						
Common Course Catalog	███ (Other)						
Universal Learning Record	███ (Other)						
Total Learning Architecture (TLA; e.g. Experience API (xAPI))	███ (Other)						
Protection of Privacy	███ (Other)						
Learning Activity Providers (e.g., PERvasive Learning System (PERLS))	███ (Other)						
Learning Science	███ (Other)						
Policy Guidance	███ (Other)						

Army	Navy	USMC	AF	Other

1.2 Training Design, Assessment, and Readiness Monitoring (cont'd)

FYDP

	2019	2020	2021	2022	2023	2024	2025
1.2.1 Data and Learning Sciences							
Advanced Proficiency Technologies		AF	AF	AF	AF	AF	
Interactive Task Learning		AF	AF	AF	AF	AF	
Advanced Analytics and Decision Making	Navy						
Fleet Adaptive Multilevel Measurement for Operations and Unit Systems (FAM2OUS)	Navy						
Commander's Risk Mitigation Dashboard (CRMD)	Navy						
Manpower Planning Tool	Navy						
1.2.2 Cognitive and Performance Modeling							
Autonomous Models, Agents for Training and Operations (AMATO)	AF						
Teachable Models for Training		AF	AF	AF	AF	AF	
Multiscale Models of Human Performance		AF	AF	AF	AF	AF	
1.2.3 Innovative Training Design and Methodologies							
Knowledge Sharing Engine (KSE)	Navy						
Interactive Task Learning		AF	AF	AF	AF	AF	

1.3 Advanced Learning Technologies

FYDP

	2019	2020	2021	2022	2023	2024	2025
1.3.1 VR/AR/MR and Integrated Simulations							
Adaptive Training for C2ISR (AOC, Cyber, ISR)	AF						
Adaptive LVC Training	AF						
VR/AR Training System for Explosive Ordnance Disposal (EOD)	Army						
Personalized Training in Immersive VR	Army						

Army	Navy	USMC	AF	Other

1.3 Advanced Learning Technologies (cont'd)

	FYDP						
	2019	2020	2021	2022	2023	2024	2025
1.3.1 VR/AR/MR and Integrated Simulations (cont'd)							
Personalized Gamified Training	███ Army	███	███				
Advanced Proficiency Technologies		███ AF	███	███	███	███	
Teachable Models for Training		███ AF	███	███	███	███	
Fleet Training Technologies (FleeT^2)	███ Navy	███					
Future Integrated Training Environment (FITE)	███ USMC	███	███	███			
Warfighter Augmented Reality	███ USMC	███	███				
3D Interactive Aircraft Carrier Operations Planning Virtual Training	███ Navy	███	███				
Investigating Low-Cost Untethered VR Technologies and Training Effectiveness in Immersive Environments	███ Navy						
LVC Fleet Synthetic Training at Sea for Forward Deployed Naval Forces (LFAS 4 FDNF)	███ Navy						
Human Performance, Training, and Education	███ USMC	███	███	███	███		
SMART-Viz			███ USMC	███	███		
1.3.2 Intelligent Tutoring Systems							
Training Technologies	███ Navy						
Learning Continuum and Performance Aid	███ Navy						
Modernizing Terrain Generation for USMC M&S	███ USMC						
Accelerating the Development of Small-Unit Decision Making (ADSUDM)	███ USMC						
Teachable Models for Training		███ AF	███	███	███	███	

Army	Navy	AF	Other

Understanding Human/Cognitive Processing [WITHIN HUMAN]

	FYDP						
	2019	2020	2021	2022	2023	2024	2025
2.1.1 Perception (unitary and Multi-Sensory)							
Multisensory Perception and Multimodal Displays	███	███	███	███	███	███	
2.1.2 Dynamic operator functional state assessment							
Cognitive Performance Optimization	███	███					
Adaptive Soldier Architecture	███	███					
A&A Campaign Zero Sum Moves Human Analysis Methodology for CEMA	███	███	███	███	███	███	
Continuous Multi-faceted Soldier Characterization for Adaptive Technology (Human Variability)	███	███	███	███	███		
Multiscale Modeling		███	███	███	███	███	
2.1.3 Cog Neuroscience/Performance augmentation							
Applied Adaptive Aiding	███	███	███				
Monitoring, Predicting and Optimizing Battlespace Awareness	███	███					
Soldier Focused Neurotechnologies	███	███					

Legend: Army (green) | Navy (blue) | AF (light blue) | Other (orange)

Human-Machine Interaction and Aiding [HUMAN-MACHINE]

Focus Area	2019	2020	2021	2022	2023	2024	2025
2.2.1 Advanced Interface Methods							
Visual Interactive Exploratory Data Analysis (VIEDA)	AF	AF					
Human Interaction with Adaptive Automation (HIAA)	AF	AF					
Human-Robot Interaction	Army	Army					
Brain-Computer Interaction	Army	Army					
Autonomy, Artificial Intelligence, and Robotics	Navy	Navy	Navy	Navy	Navy	Navy	Navy
Explainable Intelligence Underlying Efficient Integration of Cognitive-assist Agents	Army	Army					
Enhanced Tactical Communications	AF						
Visualization of Fused Info	AF	AF					
Human Language Technology	AF	AF	AF	AF	AF		
2.2.2 Intelligent Decision aiding/support							
Novel Human-Intelligent Agent Interactions	Army	Army	Army	Army			
Understanding Sociocultural Behavior	Army	Army	Army	Army			
Mine Counter Measures Task Force Planning	Navy						
Human-agent Interactions for Intelligent Squad Weapons	Army	Army	Army	Army			
ISR Analyst Performance	AF	AF	AF	AF	AF		
2.2.3 Dynamic/adaptive task allocation and Authority Transfer							
Decision Authority Delegation (DAD)	Navy	Navy	Navy	Navy	Navy	Navy	Navy
2.2.4 Trust calibration & transparency							
Human Insight and Trust (HIT)	AF	AF	AF				

Army	Navy	AF	Other

System Level Interfaces & Teaming [HUMAN-SYSTEM]	FYDP						
	2019	2020	2021	2022	2023	2024	2025
2.3.1 System analyses and HSI							
Early Human Systems Integration	████	████	████	████			
Human Factors and Organizational Design	████	████					
2.3.2 Team processes, performance, and metrics							
NGCV Human-intelligent Agent Performance Assessment Tools		████	████	████	████	████	
Crew Capability Enhancement		████	████	████	████	████	
Coordination-promoting agents for maximizing team performance	████	████					
2.3.3 Data analytics/exploitation tools							
Information Environment Assessment Nexus	████	████					
2.3.4 System Interface Design and Application							
Vigilant Spirit - Multi Role Control Station (VS-MRCS)	██						
Cross-Domain unmanned Systems (C-D UxS)	████	████					
Operational Planning Tool	██						
Manned and Unmanned Common Planning Picture	██						
Modernizing Terrain Generation for USMC M&S	████	████					
Soldier Performance in Sociotechnical Environments	██						
Adaptive Teamwork with Layered Airman-Machine Interfaces and Systems (ATLAS)	████	████	████	████	████	████	
Mission Planning & Debrief	████	████	████	████			
BATMAN III	████	████	████				

Army	Navy	AF	Joint

3.1 Sensing, Monitoring, and Assessment — FYDP

	2019	2020	2021	2022	2023	2024	2025
3.1.1 Sense and Monitor							
Molecular Signatures	AF	AF	AF				
Human Performance Monitoring and Augmentation	Navy	Navy	Navy	Navy			
Body-worn Wireless Neurophysiological Monitoring Network	Navy	Navy					
Performance Evaluation of Newly Available Sleep Assessment Devices	Navy	Navy					
Hypoxia Alert and Mitigation System	Navy	Navy					
Physiological Beacon	Navy	Navy	(open)	(open)			
OMNI	Navy	Navy					
On-Board Oxygen Generating Systems (OBOGS)	AF	AF	AF	AF			
Integrated Cockpit Sensing	AF	AF	AF				
3.1.2 Assessment							
Measuring & Advancing Soldier Tactical Readiness & Effectiveness (MASTR-E) Pilot	Army						
Fitness and Body Composition as Predictors of Musculoskeletal Injury Risk	Navy						
Human System Design Guidance for Head-Borne Systems		Army	Army	Army			
Dynamic Marksmanship Characterization: Novice vs. Expert	Army	Army					
MASTR-E Program			Joint	Joint	Joint	Joint	Joint
M2ATP	AF	AF	AF	AF			
Physical and Cognitive Overburden of Small Team Performance	Army	Army	Army				
Human Performance in Dismounted Operations	Army	Army	Army				
Incapacitation Prediction for Readiness in Expeditionary Domains			Navy	Navy (open)	Navy (open)		
Airman Data Analysis and Performance Tracking System	AF	AF	AF				
Human Performance Assessment and Recommendations for Training and Operations		Navy	Navy	Navy (open)	Navy (open)		

Army	Navy	AF	Joint

3.2 Enhancement Technologies and Techniques

	FYDP						
	2019	2020	2021	2022	2023	2024	2025
3.2.1 Training Enhancements							
Adaptive Training Protocols (ATP)	■ Navy (2019–2021), outline (2021–2022)						
FitForce Planner	■ Navy (2019–2020)						
Strengthening Health &Improving Emotional Defenses (SHIELD)	■ Navy (2019–2020)						
Neuromodulation for Operations		■ AF (2020–2024)					
3.2.2 Physical Augmentation							
Naval Noise Induced Hearing Loss	■ Navy (2019–2020)						
Exoskeletons:							
Advancement of Exoskeletons for Movement & Maneuver and Sustainment	■ Army (2019–2021)						
Determination of Lower Extremity Joint Actuation Requirements	■ Army (2019)						
Research for Advanced Soldier-PA System Interaction	■ Army (2019–2024)						
Techniques for Soldier-Exoskeleton Analysis	■ Army (2019–2022)						
Lightweight Atmospheric Dive Suit (LADS)		■ Navy (2020–2022), outline (2022–2025)					
3.2.3 Molecular Interventions & Treatments							
Gut Microbiome and Performance Nutrition	■ Army (2019–2025)						
Nutritional Factors that Support Immune Function and Muscle Recovery	■ Army (2019–2022)						
Small Intestine Gut Microbiome Benchtop Model	■ Army (2019–2020)						
Intestinal Immunity, Nutrition & Gut Microbiome: Beyond the Microbiome		■ Army (2020–2023)					
Feeding the Gut Microbiome							
PHITE: Precision High Intensity Training through Epigenetics	■ Navy (2019)						
Synthetic Biological Enhancement		■ AF (2020–2025)					
Tailored Probiotics		■ AF (2020–2025)					

Army	Navy	AF	Joint

3.3 Bioeffects	FYDP						
	2019	2020	2021	2022	2023	2024	2025
3.3.1 Laser							
Applied HEL Bioeffects	▮	▮					
Laser Protection	▮	▮					
Novel Laser Bioeffects	▮	▮					
Bioeffects for Emerging Weapon Systems and Technologies		▮	▮	▮	▮	▮	▮
3.3.2. Radio Frequency							
Tactical Decision Support Tools	▮	▮					
Novel Radio Frequency Bioeffects	▮	▮					
Airmen Protection and Weapon Effects		▮	▮	▮	▮	▮	▮
3.3.3 Novel Weapon Effects							
Non-Lethal Weapons Human Effects Center of Excellence	▮						

Backup

Acronyms

- ARAP - Applied Research for the Advancement of S&T Priorities
- BATDOK - Battlefield Assisted Trauma Distributed Observation Kit
- CCDC - U.S. Army Combat Capabilities Development Command
- DE – Directed Energy
- HFE TAG - Human Factors Engineering Technical Advisory Group
- HMT – Human Machine Teaming
- HSD - Human Systems Division
- I/ITSEC – Interservice/Industry Simulation Training & Education Conference
- IMPACT - Intelligent Multi-UxV Planner with Adaptive Collaborative Control Technologies
- IR&D TIMs – Internal Research & Development Technical Interchange Meetings
- LVC – Live, Virtual, Constructive
- MASTR-E - Measuring & Advancing Soldier Tactical Readiness and Effectiveness
- NDIA- National Defense Industrial Association
- OFP – Operational Flight Program
- PMESII - Political, military, economic, social, infrastructure, and information systems
- SLATE - Secure Live Virtual Constructive (LVC) Advance Training Environment
- TTCP – The Technical Cooperation Program

Human Systems CoI Taxonomy Evolution

Sub-Areas	Former	Current 2020 Thrusts
Personalized Assessment, Education, and Training	Personnel Selection and Assignment	Personnel Selection and Assignment
	First Principles for Training Design	Training Design, Assessment, and Readiness Monitoring
		Advanced Learning Technologies
System Interfaces and Cognitive Processes	Human Information Interpretation & Influence	Understanding Human/Cognitive Processing
	Intelligent, Adaptive Aiding	Human-Machine Interaction and Aiding
	Human-Machine Teaming	System Level Interfaces and Teaming
Protection, Sustainment, and Warfighter Performance	Critical Stressor Mitigation Strategies	Sensing, Monitoring, and Assessment
	Understanding and Quantifying the Effects of Critical Stressors	Enhancement Technologies and Techniques
		Bioeffects